CLAIMS

What is claimed is:

1. A hydrodynamic face seal for a poppet valve rotating sleeve internal combustion engine, the engine comprising a rotating sleeve which may be rotated during the operation of the engine, and a cylinder head, the face seal comprising

an annular face which may be positioned in proximity to the rotating sleeve;

the mating surface comprising

an inner sealing zone, and

an outer loading zone, such that the loading zone comprises a plurality of hydrodynamic lift features, such that the lift features create converging surfaces;

a lubricant supply means, such that the lubricant supply means provides lubricant to the mating surface, and such that a lubricant layer can be maintained between the face and the rotating sleeve.

2. The face seal of claim 1 wherein the hydrodynamic lift features are recessed lift pads.

3. The face seal of claim 1 wherein the hydrodynamic lift features are tilted pads.

4. The face seal of claim 1 wherein the lubricant supply means comprises

an oil chamber;

an annular oil supply cavity on the face positioned between the sealing zone and the loading zone; and

a plurality of supply passages from the oil chamber to the annular oil supply cavity, such that oil may be provided from the oil chamber through the annular oil supply cavity to the sealing zone and loading zone.

5. The face seal of claim 4 further comprising

a plurality of outwardly extending radial passages from the annular oil passage, such that the outwardly extending radial passages provide oil to the hydrodynamic lift features of the loading zone.

6. The face seal of claim 1 wherein the face seal is positioned within a cylinder head insert in the cylinder head, and the face seal further comprises

an outer secondary seal between the face seal and the head insert; and

a first inner secondary seal between the face seal and the head insert.

7. The face seal of claim 6 further comprising

a second inner secondary seal between the face seal and the head insert.

8. The face seal of claim 6 further comprising

a pre-load means, such that the pre-load means provides a force on the face seal toward the sleeve, thereby reducing the thickness of the lubrication layer.

9. The face seal of claim 8 wherein

the pre-load means is at least one spring positioned between the head insert and the face seal. .

10. The face seal of claim 8 wherein

the pre-load means is a plurality of springs positioned between the head insert and the face seal.

11. A poppet valved rotating sleeve internal combustion engine comprising at least one cylinder, each cylinder comprising:

a cylinder head;

a cylindrical rotating sleeve means comprising a first end in proximity to the cylinder head;

a piston means which reciprocates within the rotating sleeve means;

a combustion chamber, the chamber being the variable volume between the reciprocating piston means, the rotating sleeve means, and the cylinder head;

a piston sealing means, such that the piston sealing means provides a seal between the piston means and the rotating sleeve means;

a sleeve driving means, such that the sleeve driving means causes the rotating sleeve means to rotate in order to maintain hydrodynamic lubrication between the piston sealing means and the rotating sleeve means;

an intake means, such that fuel and air may be introduced into the combustion chamber;

an exhaust means; such that combustion gasses can be removed from the combustion chamber; and

a hydrodynamic face seal comprising

a face which may be positioned in proximity to the first end of the rotating sleeve; the face comprising

an inner sealing zone, and

an outer loading zone, such that the loading zone comprises a plurality of hydrodynamic lift features, and

a lubricant supply means, such that the lubricant supply means provides lubricant to the mating surface, and such that a lubricant layer can be maintained between the mating surface and the rotating sleeve.

12. The face seal of claim 11 wherein the hydrodynamic lift features are recessed lift pads.

13. The face seal of claim 11 wherein the hydrodynamic lift features are tilted pads.

14. The face seal of claim 11 wherein the lubricant supply means comprises

an oil chamber;

an annular oil supply cavity on the face positioned between the sealing zone and the loading zone; and

a plurality of supply passages from the oil chamber to the annular oil supply cavity, such that oil may be provided from the oil chamber through the annular oil supply cavity to the sealing zone and loading zone.

15. The face seal of claim 14 further comprising

a plurality of outwardly extending radial passages from the annular oil passage, such that the outwardly extending radial passages provide oil to the recessed lift features of the loading zone.

16. The face seal of claim 11 wherein the face seal is positioned within a cylinder head insert in the cylinder head, and the face seal further comprises

an outer secondary seal between the face seal and the head insert; and

a first inner secondary seal between the face seal and the head insert.

17. The face seal of claim 16 further comprising

a second inner secondary seal between the face seal and the head insert.

18. The face seal of claim 16 further comprising

a pre-load means, such that the pre-load means provides a force on the face seal toward the sleeve, thereby reducing the thickness of the lubrication layer.

19. The face seal of claim 18 wherein

the pre-load means is at least one spring positioned between the head insert and the face seal. .

20. The face seal of claim 18 wherein

the pre-load means is a plurality of springs positioned between the head insert and the face seal.

21. A method of sealing between the combustion chamber and the cylinder head of a rotating sleeve internal combustion engine, the engine comprising a rotating sleeve which may be rotated during the operation of the engine, the method comprising

providing a hydrodynamic face seal, the face seal comprising a face which may be positioned in proximity to a first end of the rotating sleeve; the face comprising

a sealing zone, and

a loading zone, such that the loading zone comprises a plurality of lift features;

providing a flow of lubricant to the mating surface so that a lubricant layer is maintained between the face and the rotating sleeve;

pre-loading the face seal;

maintaining a lubricant layer thickness of about 1 to 10 micrometers in the inner sealing zone;

distributing cyclic gas pressure forces from the combustion chamber during engine operation to the loading zone; and

providing lift forces with the face seal loading zone lift features to maintain the lubricant layer within the desired thickness range.

22. The method of claim 21 further comprising

maintaining a lubricant layer thickness of about 2 micrometers in the inner sealing zone.

23. A poppet valved rotating sleeve internal combustion engine comprising at least one cylinder, each cylinder comprising:

a cylinder head;

a cylindrical rotating sleeve means comprising a first end in proximity to the cylinder head, the first end comprising a plurality of hydrodynamic lift features;

a piston means which reciprocates within the rotating sleeve means;

a combustion chamber, the chamber being the variable volume between the reciprocating piston means, the rotating sleeve means, and the cylinder head;

a piston sealing means, such that the piston sealing means provides a seal between the piston means and the rotating sleeve means;

a sleeve driving means, such that the sleeve driving means causes the rotating sleeve means to rotate in order to maintain hydrodynamic lubrication between the piston sealing means and the rotating sleeve means;

an intake means, such that fuel and air may be introduced into the combustion chamber;

an exhaust means; such that combustion gasses can be removed from the combustion chamber; and

a hydrodynamic face seal comprising

a face which may be positioned in proximity to the first end of the rotating sleeve; the face comprising

an inner sealing zone, and

an outer loading zone, such that the outer loading zone is positioned substantially over the plurality of hydrodynamic lift features on the first end of the rotating sleeve; and

a lubricant supply means, such that the lubricant supply means provides lubricant to the mating surface, and such that a lubricant layer can be maintained between the mating surface and the rotating sleeve.

24. A poppet valved rotating sleeve internal combustion engine comprising at least one cylinder, each cylinder comprising:

a cylinder head;

a cylindrical rotating sleeve means comprising a first end in proximity to the cylinder head, the sleeve means including an inset portion in proximity to the first end;

a piston means which reciprocates within the rotating sleeve means;

a combustion chamber, the chamber being the variable volume between the reciprocating piston means, the rotating sleeve means, and the cylinder head;

a piston sealing means, such that the piston sealing means provides a seal between the piston means and the rotating sleeve means;

a sleeve driving means, such that the sleeve driving means causes the rotating sleeve means to rotate in order to maintain hydrodynamic lubrication between the piston sealing means and the rotating sleeve means;

an intake means, such that fuel and air may be introduced into the combustion chamber;

an exhaust means; such that combustion gasses can be removed from the combustion chamber; and

a hydrodynamic face seal comprising

a face which may be positioned in proximity to the first end of the rotating sleeve; the face comprising

an inner sealing zone, and

an outer loading zone, such that the outer loading, and

a lubricant supply means, such that the lubricant supply means provides lubricant to the mating surface, and such that a lubricant layer can be maintained between the mating surface and the rotating sleeve, and

a gas pressure activated closing force surface area, such that gas pressure on the surface area substantially offsets the axial component of gas pressure acting on the inset portion of the sleeve means.